

# *Measuring LAr purity from cosmics tracks*

*Episode #3*

LArIAT Meeting  
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*Roberto Acciarri*



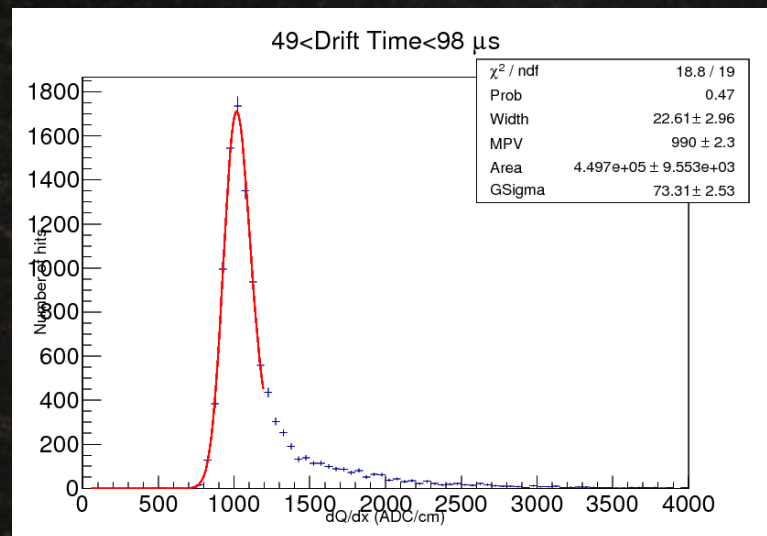
# *Previously on...*

- Two approaches adopted: standard (ICARUS and LAPD), requiring many crossing tracks, and a new one working on single tracks independently
- Standard method pros: single tracks don't need to cross the whole drift field, code inherited by LAPD (Tingjun's work) and ready for LArIAT after small modifications and tuning. Cons: Needs many days worth of data to collect enough statistics (several thousands of tracks)
- Single track method pros: reasonable measurement already with few tens of good tracks, fast computing, don't need to know track pitch. Cons: need really straight tracks crossing the whole drift field, result more sensitive to fluctuations of the hit charge
- More details on DocDB 1495 and DocDB 1507
- I'm going to show mainly work done on simulated data to validate and improve the single track method



# *In a perfect world..*

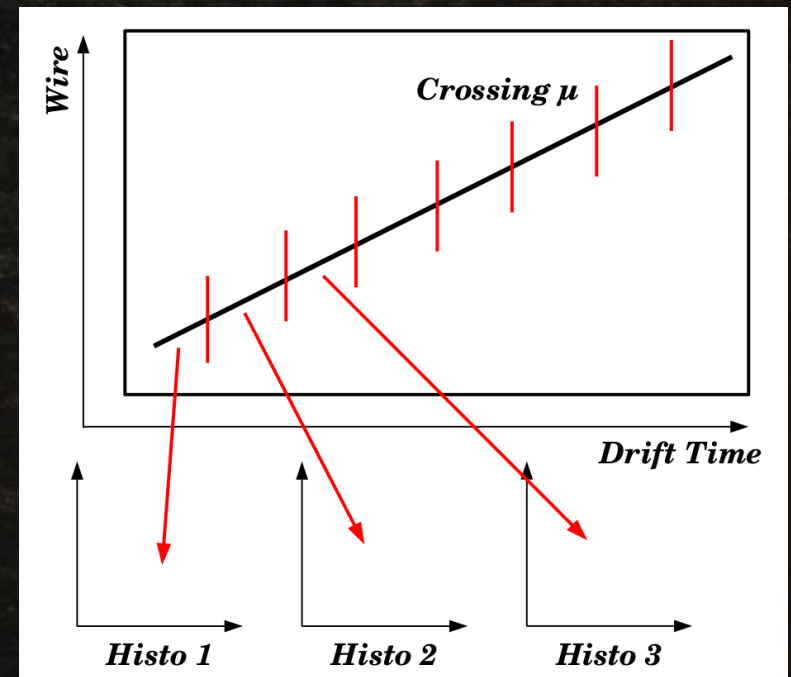
- In the lifespan of a single hit charge - from deposition into the TPC to collection on the wire planes – there is not only purity effects to be accounted for
- Charge is deposited following a Landau distribution. Collection on the wire follows a Gaussian distribution, with a sigma that depends both on electronics (constant) and on diffusion (proportional to the square root of the drift time)
- Charge should follow a distribution which is the convolution of a Landau with a Gaussian, where the sigma of the gaussian is a function of the drift time





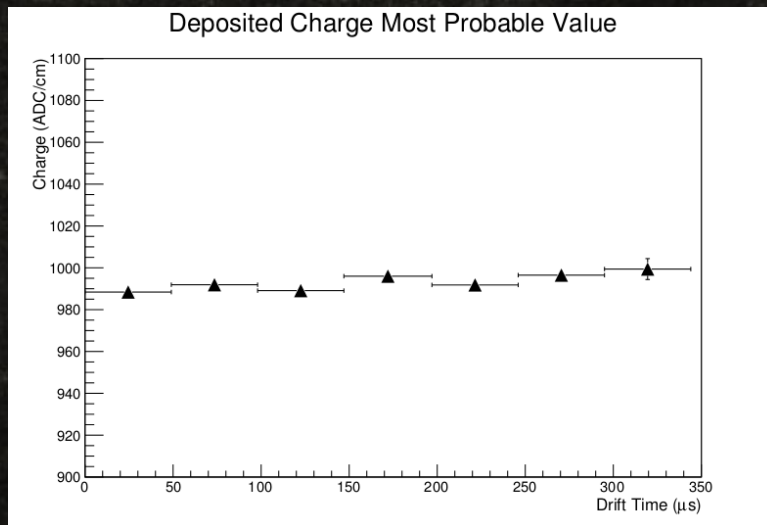
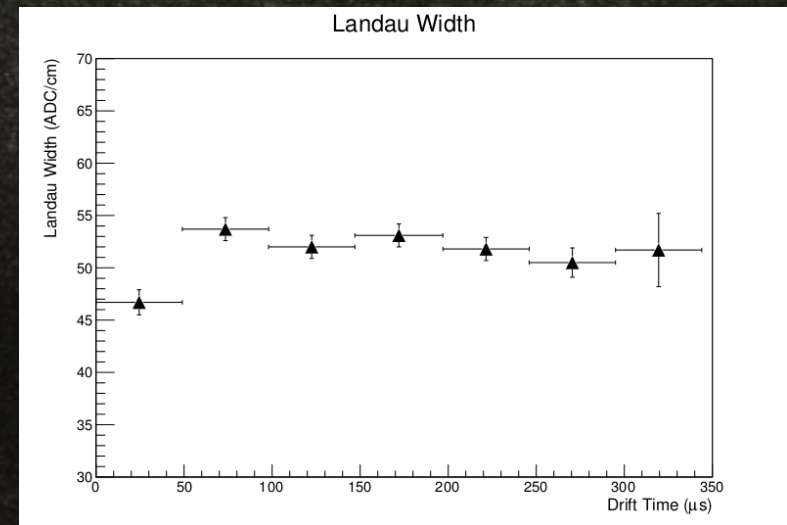
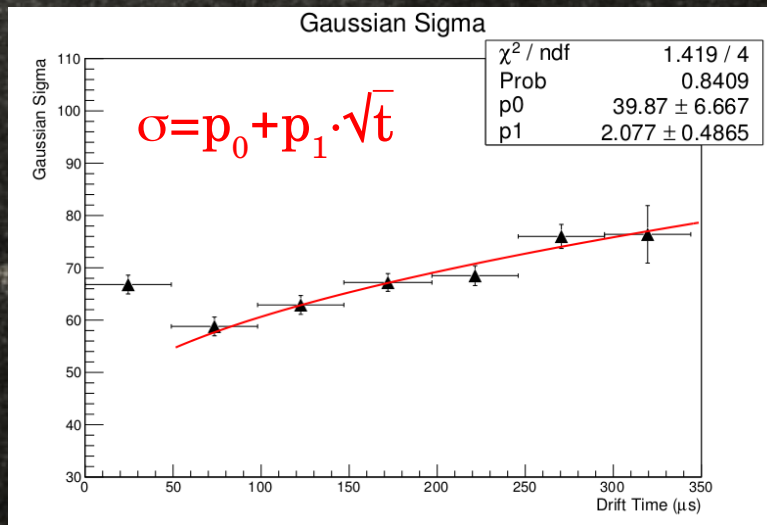
# *High purity simulation*

- Simulated a sample (5000 tracks) of crossing  $\mu$  with lifetime  $\tau = 99$  ms (no purity loss) to both verify the impact of the sigma dependency on drift time for our drift length and to verify that the fit of charge distribution with Gaus  $\otimes$  Landau function works properly
- Applied standard purity measurement method: drift time divided in 8 bins of  $\sim 50\mu\text{s}$  each. For each track, calculated the charge falling in each drift time bin and used to fill the histogram of deposited charge for that bin
- Fit each histogram independently with a Gaus  $\otimes$  Landau function and extracted the fit parameters
- Plot of parameters value as a function of drift field





# High purity simulation



- Problems in first drift time bin (correlation between Landau and Gaussian widths) and last one (no data)
- Charge MPV and Landau width constant wrt drift field (no charge loss from impurities), Gaussian sigma proportional to square root of drift time



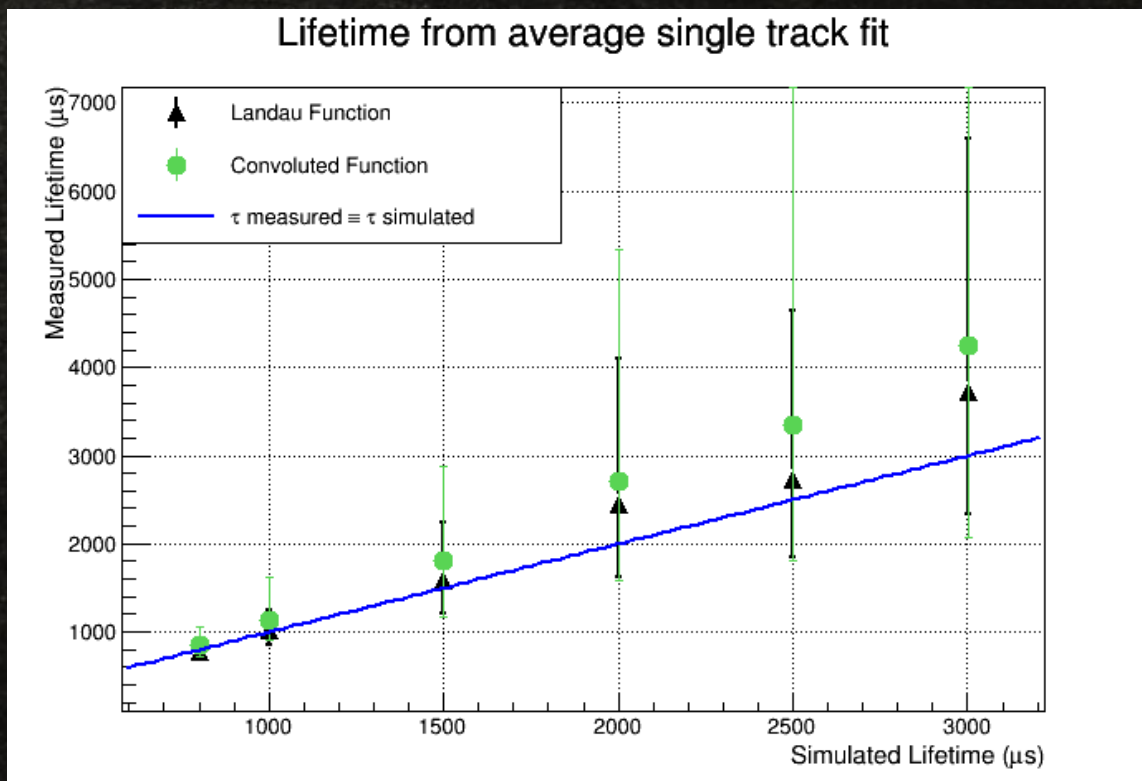
# *Single Track Method*

- ✓ Select straight tracks crossing the whole TPC
- ✓ Given a track, extract for each hit the probability  $l$  (*according to some function*) to obtain the observed  $dQ/dx$  as a function of the “uncontaminated” value  $dQ_0/dx$  and the lifetime  $\tau$
- ✓ Minimize the logarithm of the sum of  $l$  over all the hits - max likelihood  $-\ln(L)$  - respect to  $\tau$ ,  $dQ_0/dx$  and width of the probability function
- ✓ Average the values of  $\tau$  obtained for the selected tracks to be less sensitive to fluctuations in single track measurement
- ✓ Based on the previous slide, the correct probability function is Gaus  $\otimes$  Landau with the sigma of the gaussian part function of the drift time.
- ✓ This approach is the correct one, but too time expensive to be implemented: >24 hours to process something of the order of 150 good tracks!
- ✓ The alternative is to replace the convolution with a simple Landau, assuming diffusion does not play a big role and that the width of the sigma part is small enough to be absorbed in the Landau width



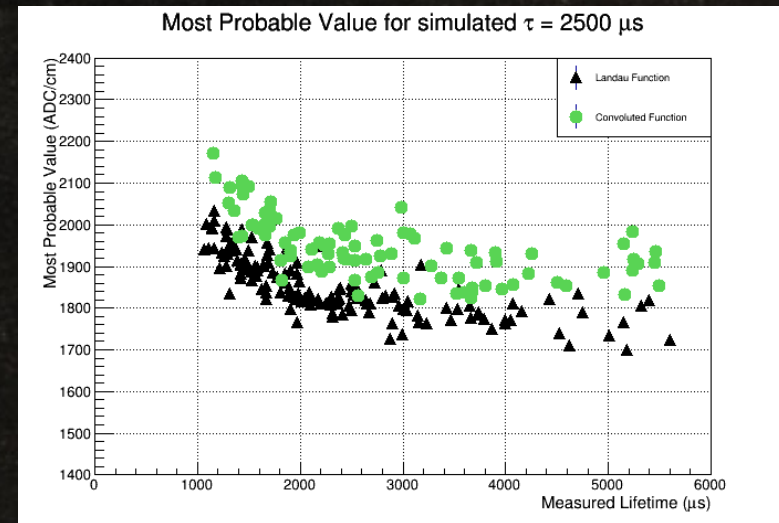
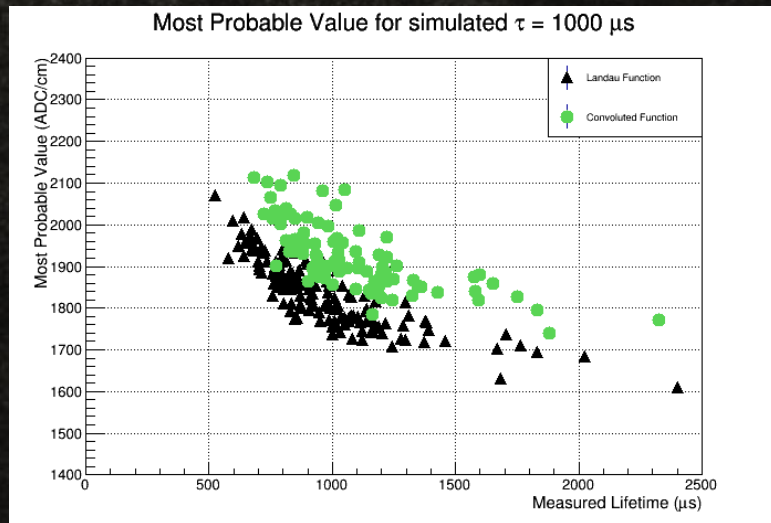
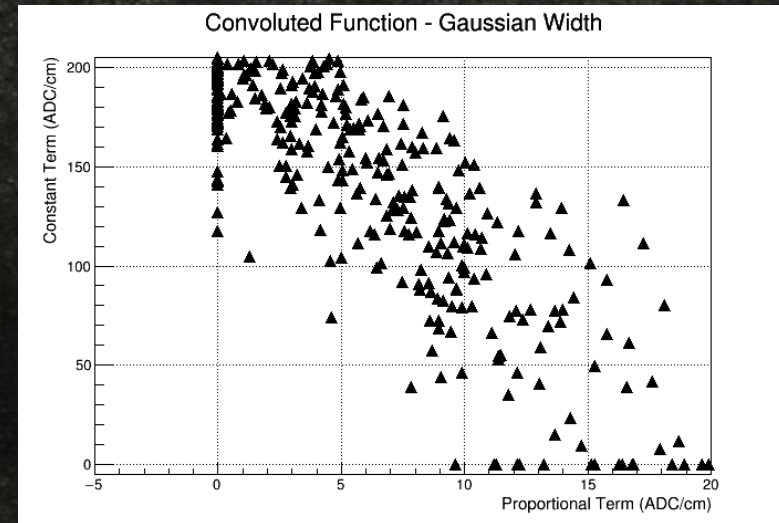
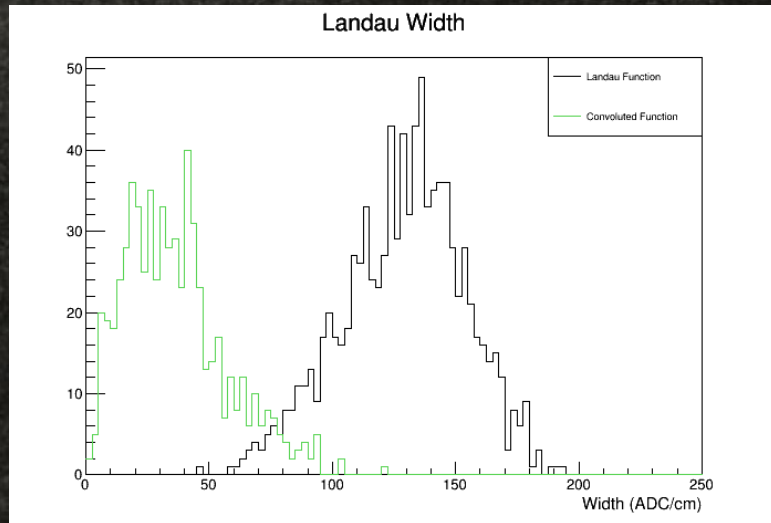
# Convolutional function VS Landau function

- ✓ To validate this assumption, samples of 4000 tracks each have been simulated for 6 different lifetime values: 800  $\mu\text{s}$ , 1000  $\mu\text{s}$ , 1500  $\mu\text{s}$ , 2000  $\mu\text{s}$ , 2500  $\mu\text{s}$ , 3000  $\mu\text{s}$
- ✓ Taken a subsample of 1000 tracks for each lifetime and measured the purity twice, once assuming a Gaus  $\otimes$  Landau function and once a Landau function



- ✓ ~10-15% events pass the cut for each sample
- ✓ Values reported are the average of single track measurements

# Convoluted function VS Landau function





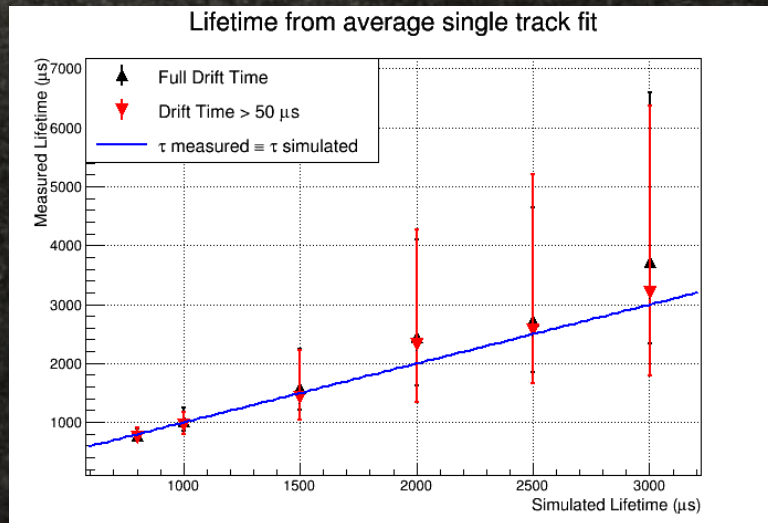
# *Landau function VS Landau function*

- ✓ The variation of the distribution width wrt drift time is stronger at low drift time values, given the square root nature of the diffusion part
- ✓ Excluding the low drift time region ( $< 50 \mu\text{s}$ ) from the measurement may improve the purity estimation
- ✓ Performed a purity estimation at each simulated lifetime with two slightly different versions of the code: in one case the probability function is a Landau and the whole drift time is considered, in the other case the probability function is still a Landau but only the drift time region  $> 50 \mu\text{s}$  is considered
- ✓ This comparison has been performed 4 times: twice on samples of 1000 tracks each, once on 100 tracks samples and once on the full 4000 tracks samples. Reason is to check at which level statistics effects the result.
- ✓ In each case, the tracks passing the selection cuts are  $\sim 10\text{-}15\%$  of the total sample

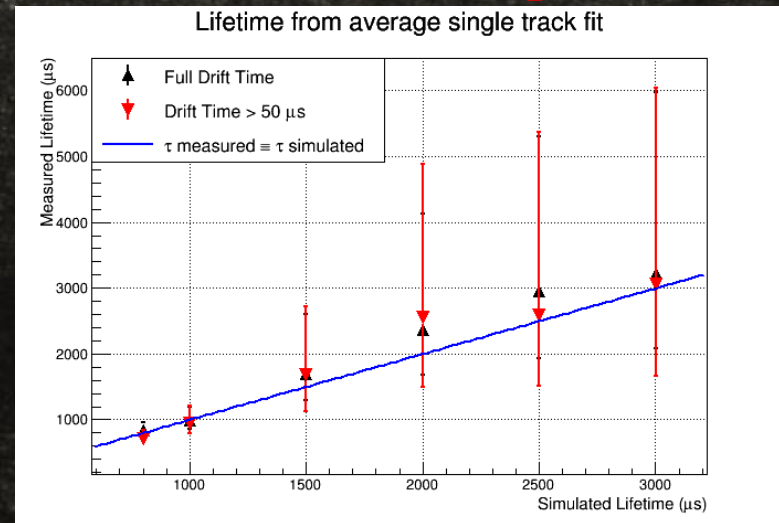


# Average Lifetime

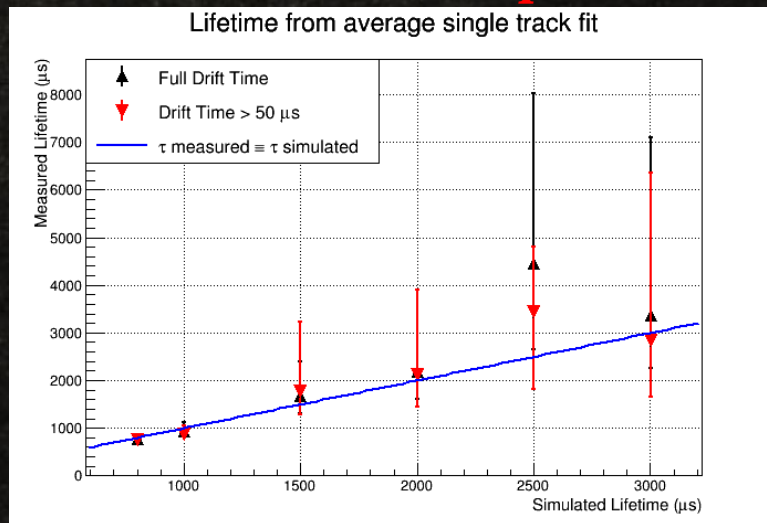
## 1000 track samples



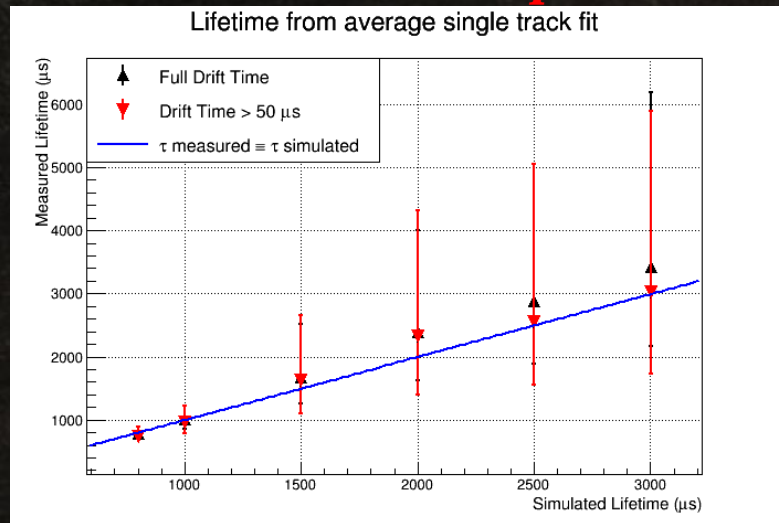
## 1000 track samples



## 100 track samples



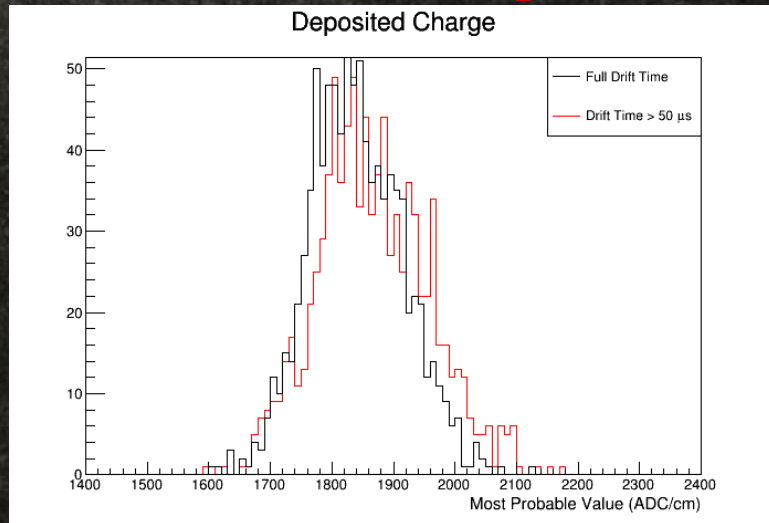
## 4000 track samples



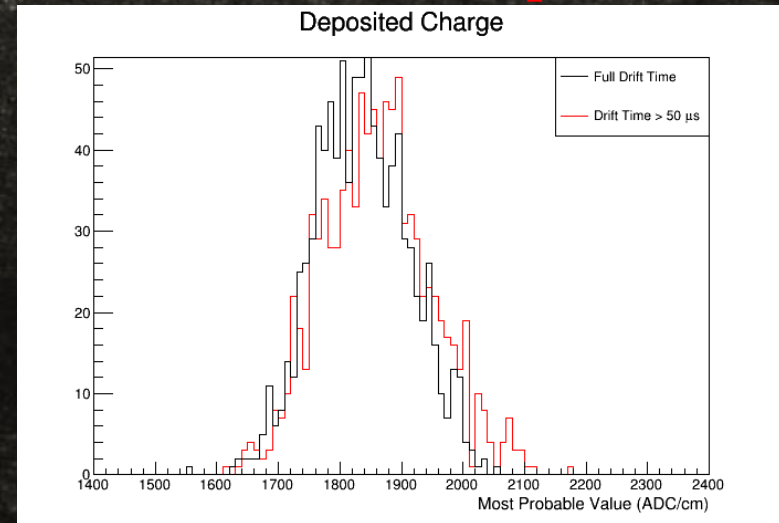


# *Deposited Charge Distribution*

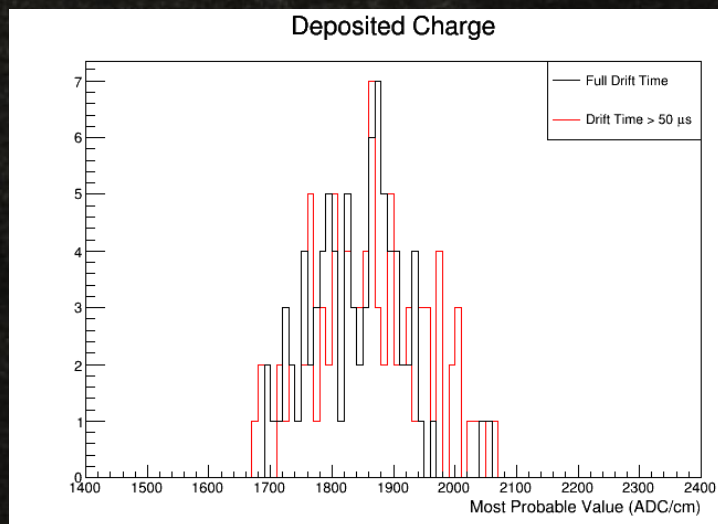
*1000 track samples*



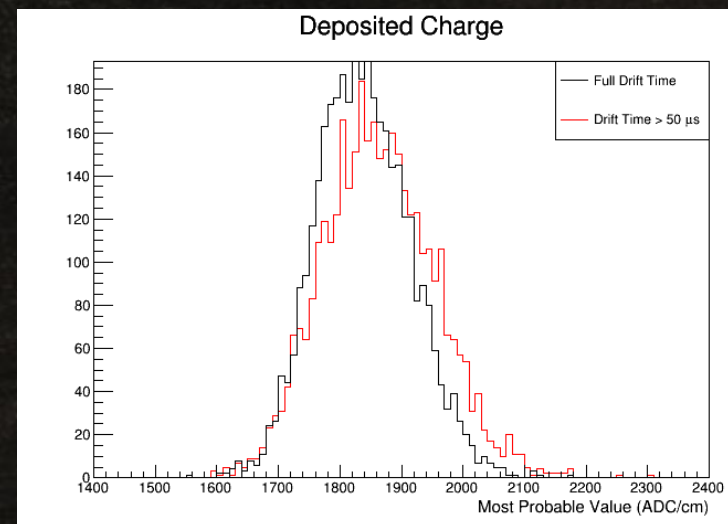
*1000 track samples*



*100 track samples*



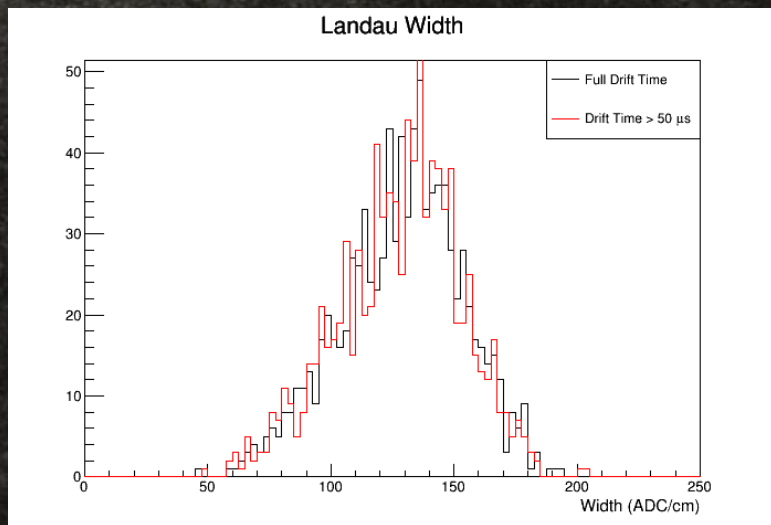
*4000 track samples*



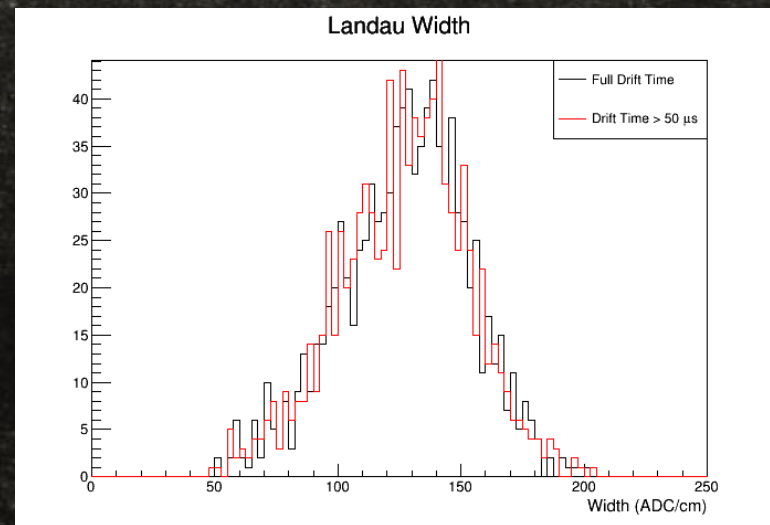


# Landau Width Distribution

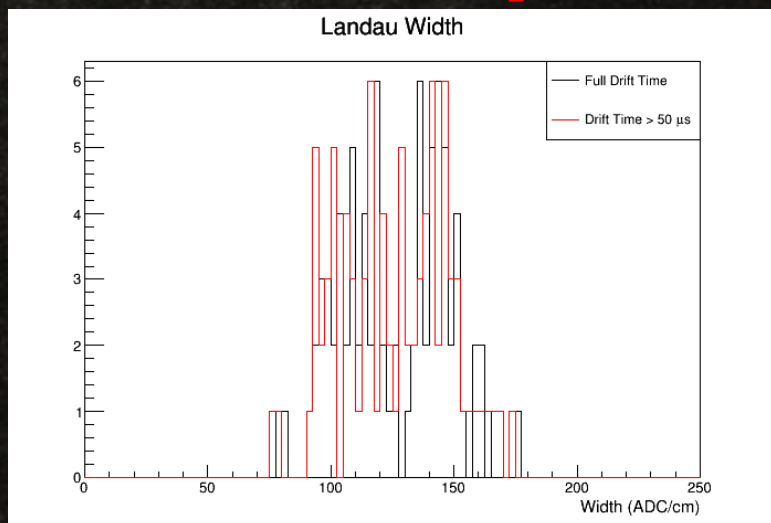
**1000 track samples**



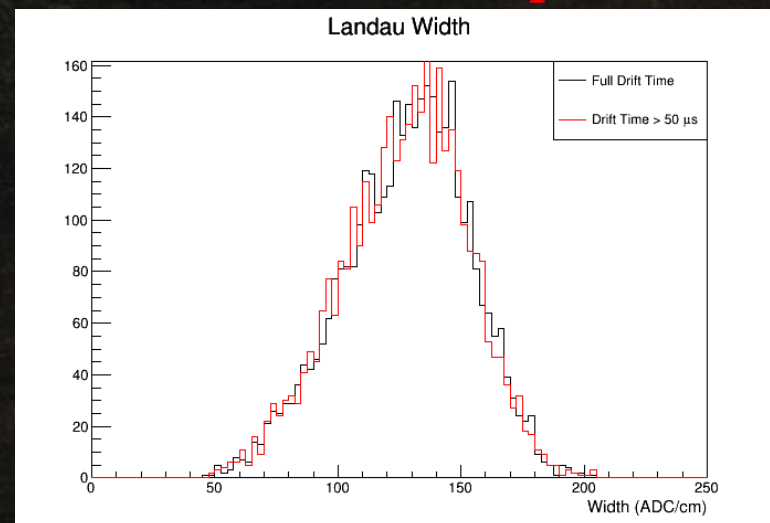
**1000 track samples**



**100 track samples**



**4000 track samples**





# ***What about real data??!!!***

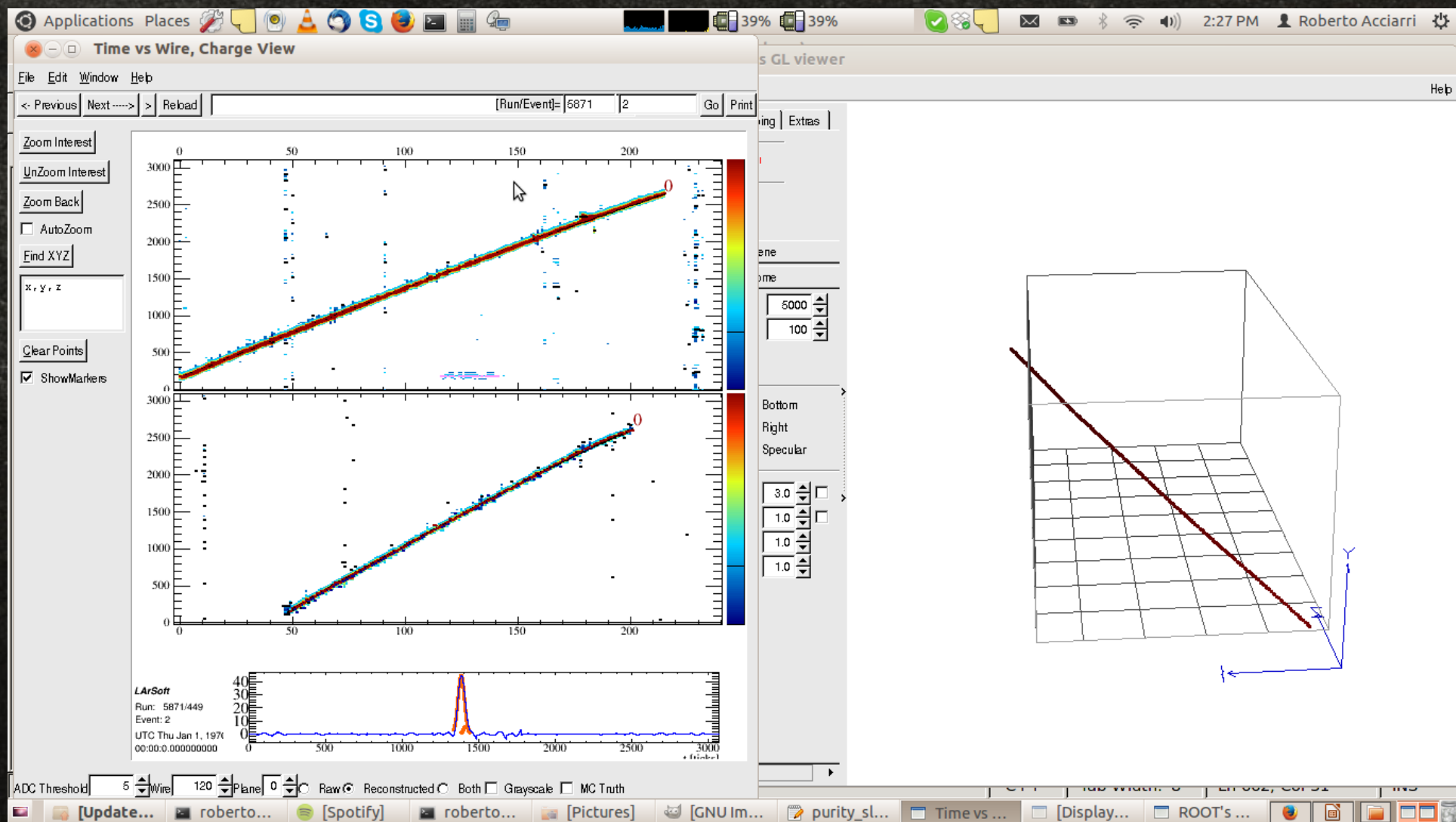
*I know, that's what everyone wants to know....*

- ✓ Fcl files to reconstruct both “sliced” data using standard (not yet tuned for LArIAT) modules and “unsliced” data using “trigger-loop implemented” modules are ready
- ✓ A set of 28 spills (from several runs) containing promisingly good cosmic tracks has been hand picked during data taking
- ✓ Reconstructed the 28 spills yesterday in the “sliced” way and started running the single track method code (Landau function, full drift time). The reco files live in my directory `/lariat/data/users/acciarri/Cosmics_for_Purity/` and are named `Reco_SRunXXXX_SpillXXX.root`, in case anyone is interested in looking at them
- ✓ Realized that some cuts needs to be modified and/or tuned... in addition, very busy events are not well handled and cause the program to crash - need to find a solution either at reconstruction or analysis level, or both



# Some example

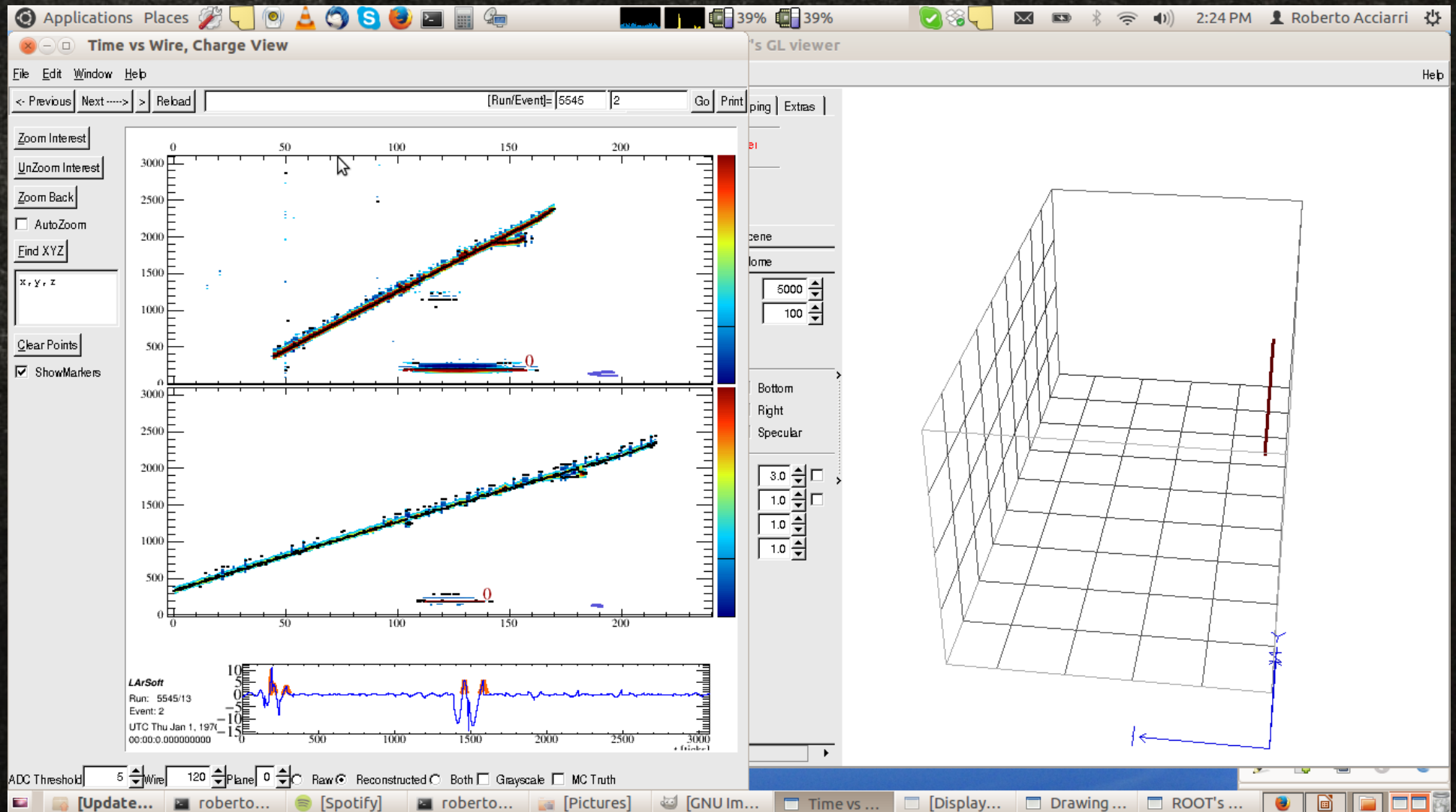
*Good case: simple track, well handled*





# Some example

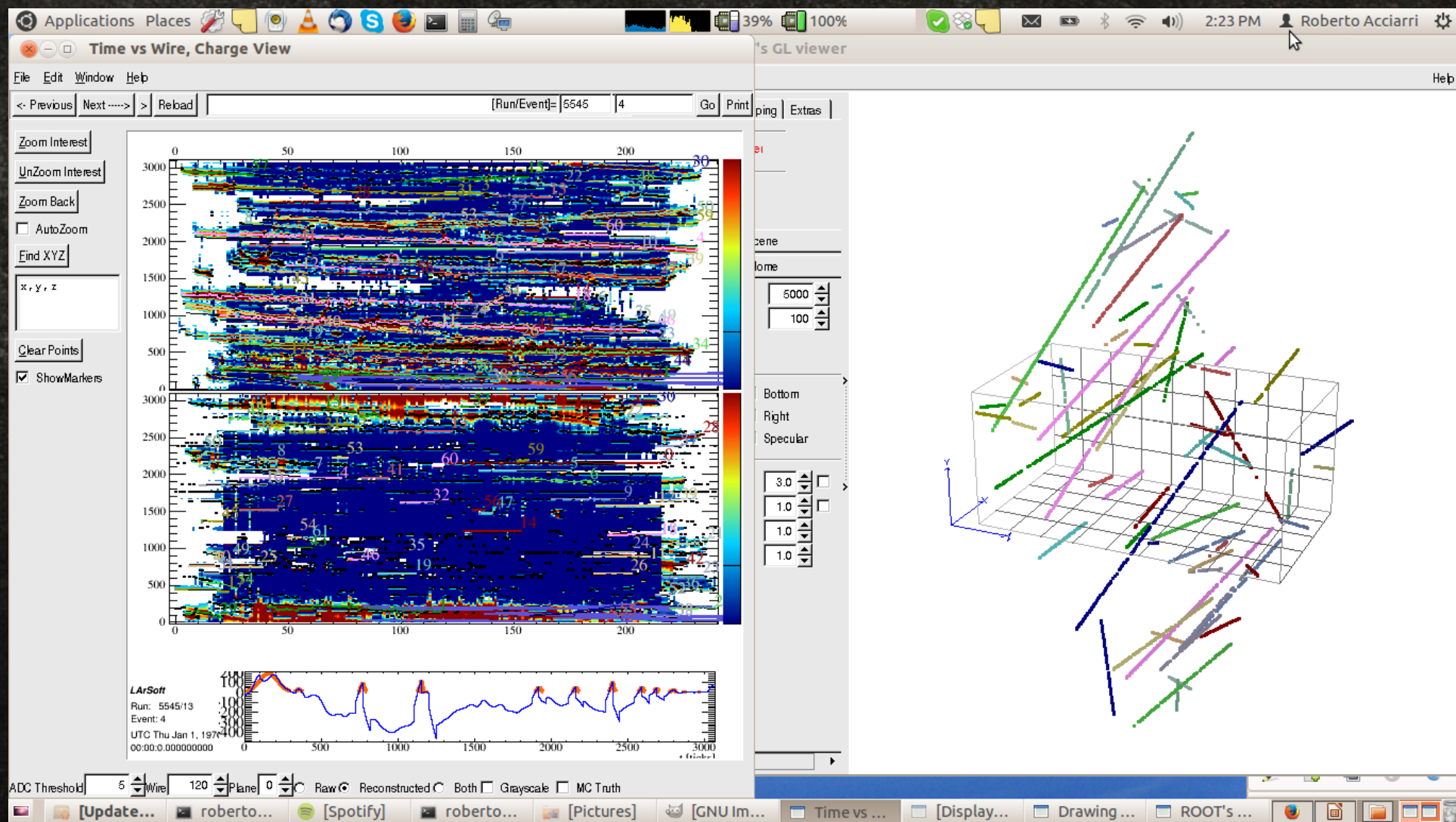
*Less good case: simple track, but the tracker prefers to reconstruct only the PMT flash.  
Note the induction wire signal...*





# Some example

*Bad case: this cause the purity program to crash, as the number of hits found is -150000*  
*Note the induction wire signal*





# *What needs to be done*

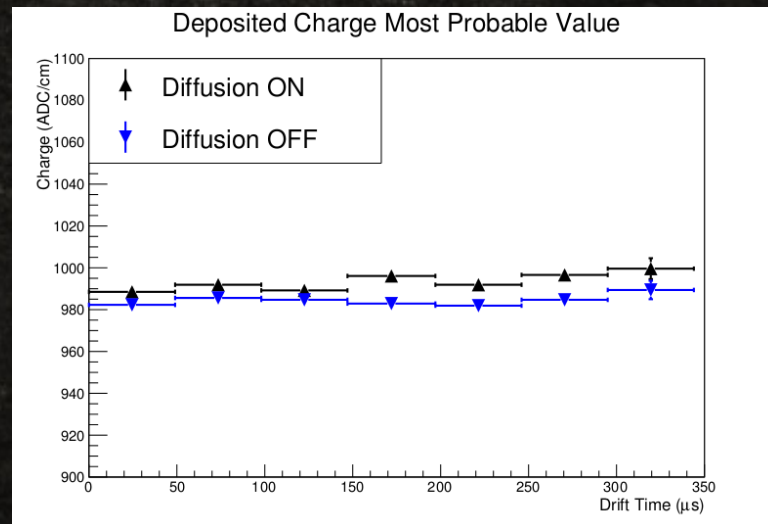
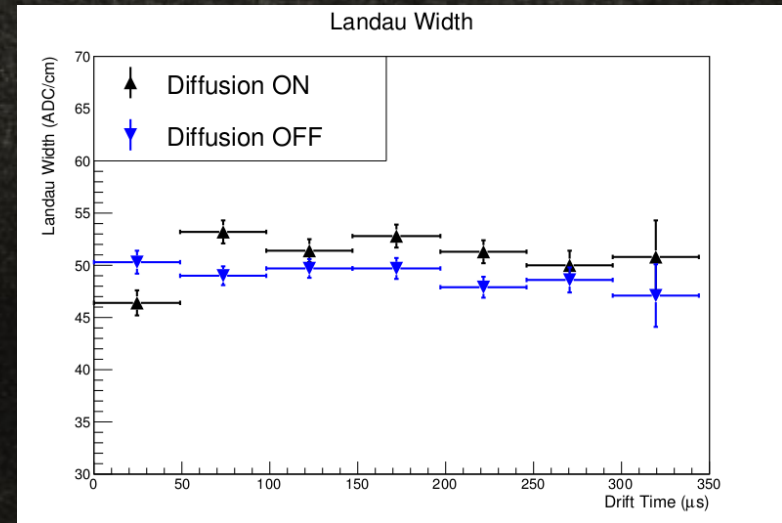
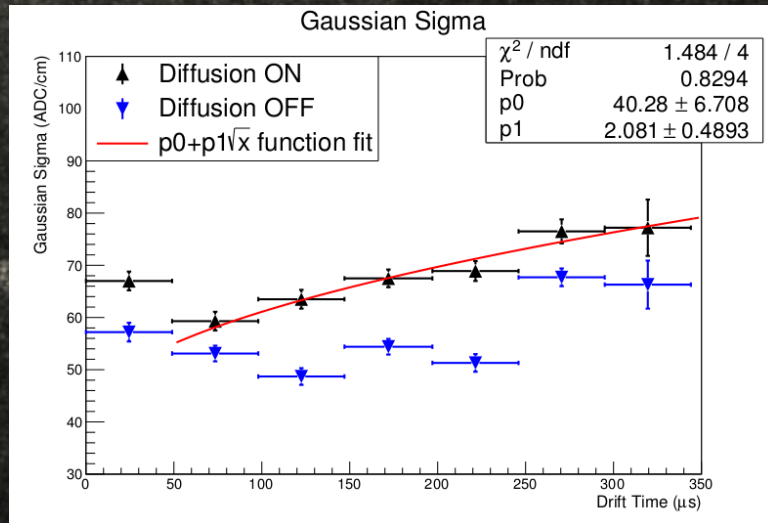
- ✓ At reconstruction level, signal deconvolution needs to be improved. This implies having a realistic electronic response function
- ✓ Once deconvolution is handled properly, parameters of the modules down the chain can be efficiently optimized
  - ✓ At analysis level, once the cuts are adjusted to real data, I want to run the code over simulated data again to make sure the purity estimation is still reliable
- ✓ Run the code on a small data sample that has been both “sliced” and “unsliced”, to make sure the two different reconstruction chains produce consistent results
  - ✓ Run the “standard” multi-track purity code on simulated and real data



**BACKUP SLIDES**



# High purity simulation



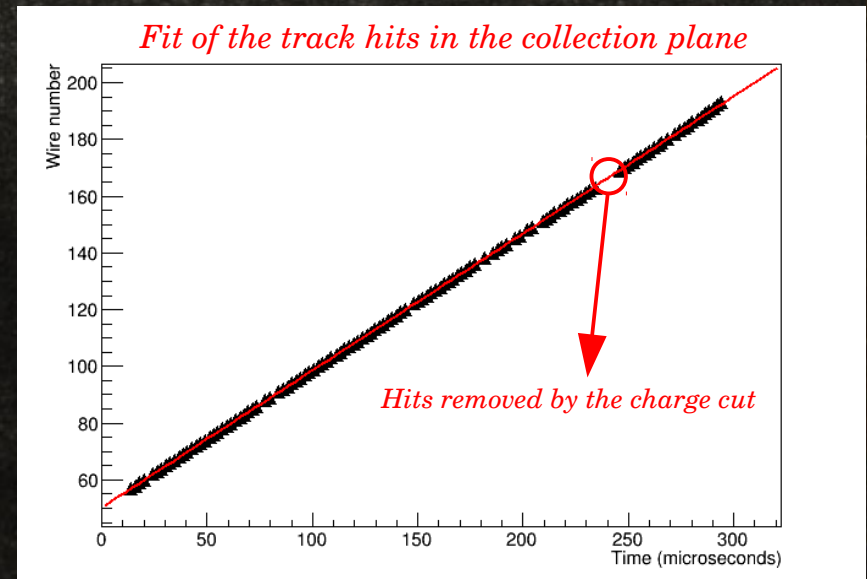
- Problems in first drift time bin (correlation between Landau and Gaussian widths) and last one (no data)
- Charge MPV and Landau width constant wrt drift field (no charge loss from impurities), Gaussian sigma proportional to square root of drift time



# Track Selection

The following cuts are applied to the events:

- ✓ TrackId==0. Cosmic Tracker is good in finding straight tracks and reconstruct visible delta rays as independent tracks.
- ✓ Track must start and end within 4 cm from wireplanes and cathode and within 10 cm from the upstream and downstream end of the TPC.
- ✓ Linear fit of the hit wire vs hit time in the collection plane must have a  $\chi^2 < 0.05$ . Hits with a time difference  $> 10\%$  respect to the fit are removed.



Make sure the tracks does not change its picth due to scattering and remove tracks with visible delta rays not reconstructed as independent tracks.

- ✓Track must contain at least 100 hits after the previous cut. This together with the previous point ensures that the track covers as much of the drift time as possible.
- ✓ Minimization is ONLY performed using the hits of the collection plane with charge contained in a band around the average chargevs drift time value

***~ 10-15% of simulated events pass these cuts***